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PROPAGATION OF TRANSIENT SIGNALS THROUGH NONLINEAR, IONIZED MED--ETC(U)
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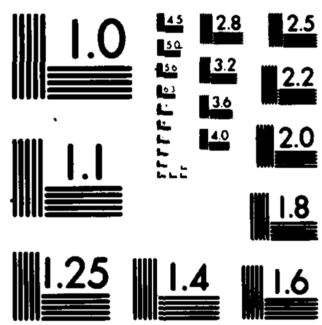

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PROPAGATION OF TRANSIENT SIGNALS THROUGH NONLINEAR, IONIZED MEDIA

FINAL SCIENTIFIC REPORT

of

RESEARCH COMPLETED

under

Grant AFOSR 78-3729

by

the Department of Electrical and Computer Engineering

of

the University of Massachusetts

Amherst, Massachusetts

Robert E. McIntosh, Principal Investigator

for period:

30 September 1978 to 30 June 1981

I. REVIEW OF ACCOMPLISHMENTS

Studies of the propagation of transient electromagnetic signals (pulses) through ionized media have been carried out at the Wave Propagation Laboratory of the University of Massachusetts under the sponsorship of the AFOST ([redacted] 78-3729). This work has resulted in a better understanding of electromagnetic pulse propagation which is relevant to HF communications, electromagnetic pulse (EMP) phenomenology and the radiation of short time-duration electromagnetic signals. A brief summary of our accomplishments is given below and a list of the resulting publications is given in Section II.

Mathematical Modeling of Electromagnetic Pulse Propagation in the Ionosphere

A propagation model has been developed [A1 and A2] which describes the reflection of HF pulses by a* randomly inhomogeneous, dispersive and absorptive ionosphere. This model has been extremely useful in predicting the distortion suffered by transmitted HF communication signals. It is seen that delay distortion, diffuse multipath and frequency incoherence effects are small compared to the discrete multipath spread resulting from large scale variations of the ionospheric electron number density. As in the case of our previous work, this model also shows that substantial pulse compression can be achieved, even when the state of the ionosphere is highly nondeterministic.

Frequency Dispersive Effects in the Ionosphere

The diurnal and random motion of the ionosphere cause both translation and spreading of the frequency spectrum of signals transmitted through the ionosphere. Ionospheric modeling by Malaga and McIntosh (conducted under

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*The reference designations A1, A2, B1, etc. refer to the publications listed in Part II.

AFOSR [redacted] 75-2763) evaluated the effect that this motion has on signal distortion. Under AFOSR [redacted] 78-3729 we have reviewed experimental research in this area [A3] and found that this model predicts frequency shifts and spreads which agree with measurements of others. We have also made measurements of HF propagation between Ottawa, Ontario and Amherst, MA. ourselves [D3] and find our model to be useful in interpreting these results. This latter work shows how traveling ionospheric disturbances (TID's) modulate the frequency dispersion of transmitted HF signals.

A Laboratory Plasma Experiment Using Microwave and Optical Diagnostic Techniques

A Laboratory experiment was conducted in which the electron number density profile of a low pressure RF-generated Argon plasma was measured concurrently using microwave and optical diagnostic techniques [A4]. The experimental system is of interest because the geometry of the plasma allows determination of the electron content at various points inside the plasma. A careful comparison of the optical emission and the electron density as diagnosed by the microwave system indicates that the steady-state corona model is relevant to the plasma under study.

A Study of the Optimum Radiation of Electromagnetic Pulses

A peripheral study, which occurred as a natural spin-off of optimum pulse propagation studies, has yielded some interesting results in the area of antennas for pulse radiation. We have used general variational calculus procedures to determine the performance bounds of antennas which are designed to radiate extremely short time-duration electromagnetic pulses. Examples are also developed which suggest that other synthesis techniques should be developed. Such techniques should result in increased efficiency in radiating electromagnetic pulses.

II. PUBLICATIONS RESULTING FROM WORK CONDUCTED UNDER GRANT AFOSR 78-3729

JOURNAL PAPERS

A. *Published*

A1 "Analysis of HF Pulse Reflection from a Randomly Varying Ionosphere," A. Malaga and R. E. McIntosh, IEEE Transactions on Antennas and Propagation, Vol. AP-27, No. 4, July 1979, pp. 508-516.

Abstract.- The reflection of high-frequency (HF) pulses by a randomly inhomogeneous, dispersive, and absorbing ionosphere is considered. The distortion of the transmitted pulses due to the intrinsic ionosphere dispersion, multipath effects and frequency incoherence is related to the spatial, temporal, and frequency dependent characteristics of both the ionosphere and the troposphere. The envelope broadening of a constant-carrier pulse due to the dispersion (delay distortion) and randomness of the media (diffuse multipath) is seen to be small compared to the discrete multipath spread resulting from variations of the ionosphere's index of refraction with height. In the case of chirp-pulse transmission, pulse compression in the range of 20-30 dB may be achieved provided the frequency sweep of the transmitted pulse is matched to the slope of the delay of the channel and the bandwidth of the chirp pulse is large enough (0.1-10% of the center frequency).

A2 "Time Dispersion of Electromagnetic Pulses by the Ionosphere," R. E. McIntosh and A. Malaga, Radio Science, Vol. 15, No. 3, May-June, 1980, pp. 645-654.

Abstract.- This paper reviews the temporal dispersive effects suffered by electromagnetic pulses during transmission or reflection by the ionosphere. A qualitative description of intrinsic plasma, geometrical (refractive and diffractive), and geomagnetic dispersion is presented. Also, tables that summarize previous research studies are given to indicate the variety of pulse signal formats and ionospheric conditions that have been considered.

A3 "Frequency Dispersion in the Ionosphere: A Mini review," R. E. McIntosh and A. Malaga, IEEE Transactions on Antennas and Propagation, Vol. AP-29, No. 5, September, 1981, 3 pp.

Abstract.- We review various studies which investigate and characterize the nature of ionospheric changes which cause frequency dispersion (i.e., Doppler shifts and spreading of the frequency spectrum) of signals propagated through the ionosphere. We also indicate those theoretical approaches which have promise for future work.

A4 "Optical Emission from a Low-density Argon Plasma," R. E. McIntosh and M. S. Kotfila, IEEE Transactions on Plasma Science, Vol. PS-9, No. 2, June, 1981, pp 63-67.

Abstract.- In many laboratory experiments, the plasma parameters do not satisfy the requirements of the various theoretical radiation models that are needed for spectral plasma diagnostics. We report here a coaxial system from which we determine the empirical relationship between the electron number density of a low-pressure argon plasma and the intensity of atomic line emission. This system is unique in that it allows the concurrent determination of electron number density and line emission intensity at various locations in the plasma.

Dependence of emission intensity on the neutral background pressure and the strength of the microwave pulse, which generates the plasma suggests that the steady-state corona model is relevant for this sytem.

A5 "Bounds on the Optimum Performance of Planar Antennas for Pulse Radiation," R. E. McIntosh and J. E. Sarna, to appear in the *IEEE Transactions on Antennas and Propagation*, Vol. 30, 1982, 15 pp.

Abstract.- The general problem of optimizing the design of planar electromagnetic pulse radiators is discussed in this paper. We show that bounds on the performance of such radiators can be determined by formulating field qualities as inner products and solving a variational problem. Results of a simple example are given where the bound on the peak electric field is found for a finite-sized radiator having a current distribution which is frequency band-limited. The bound on the peak electric field component along an arbitrary orientation direction in the radiator's far field is also presented. These results provide insight into the synthesis of electromagnetic pulse radiators but further work is necessary if the technique discussed here is to lead to the design of improved electromagnetic pulse antennas.

B. *In preparation*

B1 "Mathematical Modeling of Ionospheric HF Communication Channels," R. E. McIntosh, to be submitted to the special issue of *Radio Science* on the URSI Open Symposium on Mathematical Models of Radio Propagation.

TECHNICAL CONFERENCE PUBLICATIONS AND REPORTS

C. *Conferences*

C1 "Optimum Pulse Radiation by Planar Antennas," R. E. McIntosh and J. E. Sarna, paper presented at the USNC/URSI Meeting of Commission B in Seattle, Washington, June, 1979.

C2 "Time Spreading of Transient Pulses by the Ionosphere," R. E. McIntosh, paper presented at the USNC/URSI Meeting held in Quebec, June 4, 1980.

C3 "Mathematical Modeling of Ionospheric HF Communication Channels," R. E. McIntosh, paper to be presented at the XX General Assembly of URSI on August 18, 1981 in Washington, D.C.

D. *Technical Reports*

D1 "Concurrent Microwave and Spectral Diagnostics of a Low-Density Argon Plasma," M. S. Kotfila and R. E. McIntosh, UMass School of Eng. Tech. Rep. ECE-EP-80-1, March, 1980, 50 pp.

D2 "Optimal Electromagnetic Pulse Radiators," UMass Eng. Tech. Rep. No. ECE-EP-79-2, May 1979, 120 pp.

D3 "Measurement and Calculations of Doppler Shifted HF Waves Reflected from a Disturbed Ionosphere," A. D. Humason and R. E. McIntosh, to be published as a UMass Eng. Tech. Report, August, 1981, 43 pp.

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The durnal and random motion of the ionosphere cause both translation and spreading of the frequency spectrum of signals transmitted through it. A predictive model was built and compared to experimental data and found to successfully predict frequency shifts and spreads induced by ionospheric inhomogenieties. Another model was developed to describe the reflection of HF pulses by a randomly inhonogeneous, dispersive and absorptive ionosphere. It is seen that delay distortion, diffuse multipath and frequency incoherence effects are small compared to the discrete multipath spread resulting from large

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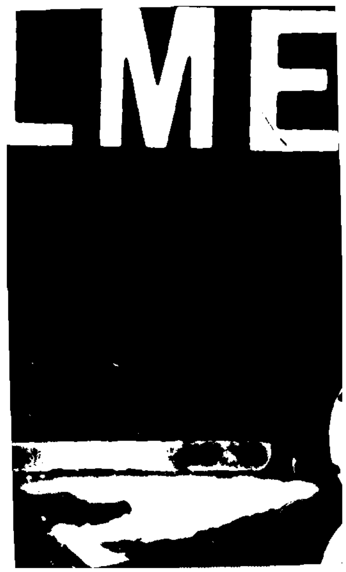
scale variations of the ionospheric electron number density. In laboratory experiments the electron number density profile of a low pressure RF-generated Argon plasma was measured concurrently using microwave and optical diagnostic techniques. In a peripheral study, interesting results in antenna performance for efficient pulse radiation were found.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